Chapter 5. Macrobenthic Communities

Introduction

Small invertebrates (macrofauna) that live within or on the surface of soft-bottom habitats are monitored by the City of San Diego (City) to examine potential effects of wastewater discharge on the marine benthos from both the Point Loma and South Bay Ocean Outfalls (PLOO and SBOO, respectively). These benthic macrofauna are targeted for monitoring because they are known to play critical ecological roles in marine environments along the Southern California Bight (SCB) coastal shelf (Fauchald and Jones 1979, Thompson et al. 1993a, Snelgrove et al. 1997). In conjunction with their ecological importance, many benthic species are relatively stationary and long-lived and they integrate the effects of pollution or disturbance over time (Hartley 1982, Bilyard 1987). Various species also respond differently to environmental stressors, and monitoring changes in individual populations or more complex communities can help identify locations susceptible to anthropogenic impacts (Pearson and Rosenberg 1978, Bilyard 1987, Warwick 1993, Smith et al. 2001). For example, pollution-tolerant species are often opportunistic and predictably outcompete others in impacted environments. In contrast, pollution-sensitive species decrease in response to toxic contamination, oxygen depletion, nutrient loading, or other forms of environmental degradation (Gray 1979). Consequently, assessment of benthic community structure has become a major component of many ocean monitoring programs.

The structure of marine macrobenthic communities is influenced by natural factors such as ocean depth, sediment composition (e.g., percent of fine versus coarse sediments), sediment quality (e.g., contaminant loads, toxicity), oceanographic conditions (e.g., temperature, dissolved oxygen, nutrient levels, currents), and biological interactions (e.g., competition, predation, bioturbation). For example, assemblages on the SCB coastal shelf typically vary along depth gradients and/or with sediment grain size (Bergen et al. 2001). Therefore, an understanding of background or reference conditions is necessary to determine whether differences in community structure may be related to anthropogenic activities. Such information is available for the monitoring area surrounding the PLOO and the San Diego region in general (e.g., City of San Diego 1999, 2011, 2012, Ranasinghe et al. 2003, 2007, 2010, 2012).

The City relies on a suite of scientifically-accepted indices and statistical analyses to evaluate changes in local marine invertebrate communities. For example, the benthic response index (BRI), Shannon diversity index, and Swartz dominance index are used as metrics of invertebrate community structure, while multivariate analyses are used to detect spatial and temporal differences among communities (e.g., Warwick and Clarke 1993, Smith et al. 2001). The use of multiple analyses provides better resolution than single parameters, and some include established benchmarks for determining anthropogenically-induced environmental impacts. For example, the BRI was developed specifically for use in the SCB with values <25 indicative of reference conditions and values >34 characteristic of degraded habitats. All together, the data are used to determine whether invertebrate assemblages in the San Diego region are similar to those from habitats with similar depth and sediment characteristics, or whether observable impacts from outfalls or other sources occur. Minor organic enrichment caused by wastewater discharge should be evident through an increase in species richness and abundance, whereas major impacts should result in decreases in overall species diversity and richness coupled with dominance by a few pollution-tolerant species (Pearson and Rosenberg 1978).

This chapter presents analyses and interpretations of the macrofaunal data collected during calendar

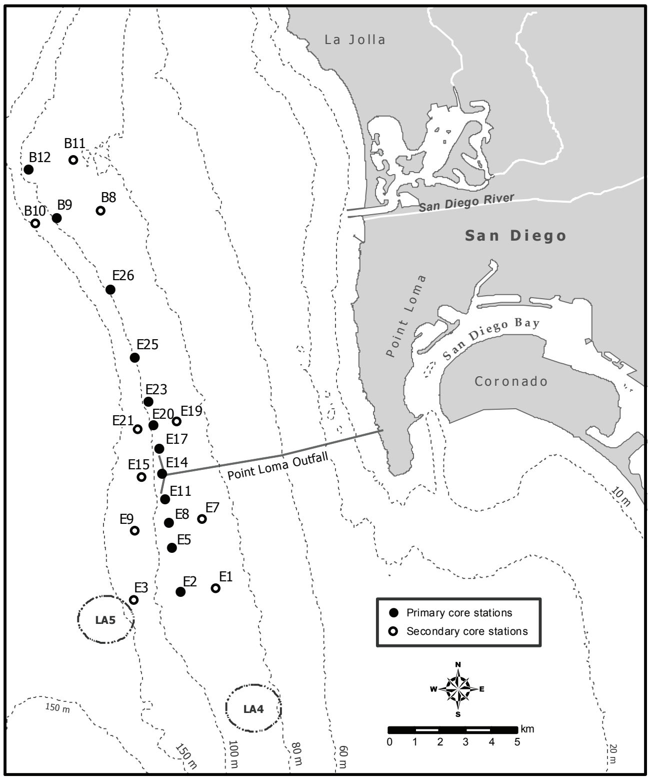

Figure 5.1
Benthic station locations sampled around the Point Loma Ocean Outfall as part of the City of San Diego's Ocean Monitoring Program.

year 2011 at fixed benthic monitoring stations surrounding the PLOO. Included are descriptions of benthic community structure and comparisons of the different invertebrate communities in the region. The primary goals are to: (1) document the benthic macrofaunal communities present during the year, (2) determine the presence or absence of biological impacts associated with wastewater discharge, and (3) identify other potential natural and anthropogenic sources of variability to the local marine ecosystem.

Materials and Methods

Collection and Processing of Samples

Benthic samples were collected at 22 fixed stations in the PLOO region during January and July 2011 (Figure 5.1). These stations range in depth from 88 to 116 m and are distributed along or adjacent to three main depth contours. These sites included 17 'E' stations ranging from approximately 5 km south to 8 km north of the outfall, and five 'B' stations located about 10–12 km north of the tip of the northern diffuser leg (see Chapter 1). The four stations considered to represent "nearfield" conditions (i.e., E11, E14, E15 and E17) are located within 1000 m of the outfall wye or diffuser legs.

Two replicate samples for benthic community analyses were collected per station during each survey using a double 0.1-m^2 Van Veen grab. The first sample was used for analysis of macrofauna, while the adjacent grab was used for sediment quality analysis (see Chapter 4). A second macrofaunal grab was then collected from a subsequent cast. Criteria established by the USEPA to ensure consistency of grab samples were followed with regard to sample disturbance and depth of penetration (USEPA 1987). All samples were sieved aboard ship through a 1.0-mm mesh screen. Macrofaunal organisms retained on the screen were collected and relaxed for 30 minutes in a magnesium sulfate solution and then fixed with buffered formalin. After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All macrofauna were sorted from the debris into major taxonomic groups by a subcontractor and then identified to species (or the lowest taxon possible) and enumerated by City marine biologists. All identifications followed nomenclatural standards established by the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT 2011).

Data Analyses

Each grab sample was considered an independent replicate for analysis. The following community structure parameters were calculated for each station per 0.1-m^2 grab: species richness (number of species), abundance (number of individuals), Shannon diversity index (H'), Pielou's evenness index (J'), Swartz dominance (see Swartz et al. 1986, Ferraro et al. 1994), and benthic response index (BRI; see Smith et al. 2001). Additionally, the total or cumulative number of species among all grabs (n=4) was calculated for each station.

Comparisons to historical ranges are based on data collected at the PLOO grid stations from 1991 through 2010, while comparisons to tolerance intervals are based on data from randomly selected regional stations sampled between 1994–2003 (City of San Diego 2007).

To further examine spatial patterns among benthic communities in the PLOO region, multivariate analyses were conducted using PRIMER (Clarke and Warwick 2001, Clarke and Gorley 2006). Macrofaunal abundance data were square-root transformed to lessen the influence of the most abundant species and increase the importance of rare species, and a Bray-Curtis similarity matrix was created using sediment type (see Appendix C.2) as a factor. A 1-way ANOSIM (maximum number of permutations = 9999) was conducted to determine whether communities varied by sediment type across the region. To visually depict the relationship of individual grab samples to each other based on macrofaunal composition, hierarchical agglomerative clustering (cluster analysis) with group-average linking was conducted. Similarity profile (SIMPROF) analysis was used to confirm non-random structure of resultant clades in the dendrogram (Clarke et al. 2008), and major ecologically-relevant clusters supported by SIMPROF were retained at >42.3% similarly. Similarity percentages (SIMPER) analyses were used to determine which organisms were responsible for the greatest contribution to within-group similarities (i.e., characteristic species), and to identify which species accounted for: (1) significant differences identified through ANOSIM, and (2) differences among clades occurring in the dendrogram.

A BACIP (Before-After-Control-Impact-Paired) statistical model was used to test the null hypothesis that there have been no changes in select community parameters due to operation of the PLOO (Bernstein and Zalinski 1983, Stewart-Oaten et al. 1986, 1992, Osenberg et al. 1994). The BACIP model compares differences between control (reference) and impact sites at times before (July 1991–October 1993) and after (January 1994–July 2011) an impact event (i.e., the onset of discharge). The analyses presented in this report are based on 2.5 years (10 quarterly surveys) of before impact data and 18 years (55 quarterly or semi-annual surveys) of after impact data. The 'E' stations, located between ~0.1 and 8 km of the outfall, are considered most likely to be affected by wastewater discharge (Smith and Riege 1994). Station E14 was selected as the impact site for all analyses; this station is located near the boundary of the Zone of Initial Dilution (ZID) and probably is the site most susceptible to impact. The 'B' stations are located farther from the outfall (>10 km north) and were originally designed to be reference or control sites. However, benthic communities differed between the 'B' and 'E' stations prior to discharge (Smith and Riege 1994, City of San Diego 1995). Thus, two stations (E26 and B9) were selected to represent separate control sites in the BACIP tests. Station E26 is located 8 km north of the outfall and is considered the 'E' station least likely to be impacted, while previous analyses suggested station B9 was the most appropriate 'B' station for comparison with the 'E' stations (Smith and Riege 1994, City of San Diego 1995). Six dependent variables were analyzed, including number of species (species richness), macrofaunal abundance, the benthic response index (BRI), and abundances of three taxa considered sensitive to organic enrichment. These indicator taxa include ophiuroids in the genus *Amphiodia* (mostly *A. urtica*), and amphipods in the genera *Ampelisca* and *Rhepoxynius*. All BACIP analyses were interpreted using one-tailed paired t-tests with a type I error rate of $\alpha = 0.05$.

Results

Community Parameters

Species richness

A total of 532 taxa were identified during the 2011 PLOO surveys. Of these, 419 taxa (79%) were identified to species, 64 to genus, 21 to family, 14 to order, 11 to class, and 3 to phylum. Most taxa occurred at multiple sites, although about 22% ($n = 119$) represented taxa recorded only once. No new species were found in the region. Average species richness

Table 5.1

Summary of macrofaunal community parameters for PLOO benthic stations sampled during 2011. Tot Spp = cumulative no. of species for the year; SR = species richness (no. species/0.1 m^2); Abun = abundance (no. individuals/0.1 m^2); H' = Shannon diversity index; J' = evenness; Dom = Swartz dominance; BRI = benthic response index. Data for each station are expressed as annual means (n=4 grabs) except Tot Spp (n=1). Stations are listed north to south from top to bottom.

	Station	Tot Spp	SR	Abun	H'	J'	Dom	BRI
88-m Depth Contour	B11	217	98	242	4.1	0.90	42	12
	B8	132	59	147	3.4	0.83	25	8
	E19	152	70	220	3.6	0.85	26	12
	E7	170	76	241	3.7	0.86	28	12
	E1	156	73	272	3.1	0.72	20	8
98-m Depth Contour	B12	210	116	430	4.2	0.88	40	14
	B9	192	102	311	4.1	0.88	40	10
	E26	151	88	282	3.9	0.87	30	10
	E25	172	102	378	4.0	0.87	34	14
	E23	159	84	301	3.8	0.87	30	14
	E20	145	76	260	3.8	0.89	28	15
	E17[a]	151	76	290	3.8	0.88	26	15
	E14[a]	165	88	333	3.8	0.85	30	22
	E11[a]	156	82	287	3.8	0.87	28	14
	E8	161	84	254	4.0	0.89	33	11
	E5	169	79	232	3.9	0.88	32	10
	E2	182	94	302	3.8	0.85	34	13
116-m Depth Contour	B10	188	98	312	4.0	0.88	36	14
	E21	174	100	352	4.0	0.87	35	14
	E15[a]	195	84	244	4.0	0.90	36	15
	E9	211	112	274	4.4	0.93	52	9
	E3	205	108	304	4.3	0.92	46	12
All Grabs	Mean	173	89	285	3.9	0.87	33	13
	95% CI	11	4	15	0.07	0.01	2	0.8
	Min	132	47	88	2.3	0.58	8	3
	Max	217	129	467	4.5	0.95	58	24

[a] = nearfield station

ranged from 59 taxa per 0.1 m^2 grab at station B8 to 116 taxa per grab at station B12 (Table 5.1). Both of these reference stations are located ≥10 km north of the outfall. Although the number of species per site varied spatially, there were no clear patterns relative to distance from the discharge site. Values recorded during the year were within the historical range of 49–160 taxa/grab reported between 1991–2010. Further, species richness at 91% of the stations was within the tolerance intervals of 72–175 taxa/grab calculated for the region.

Macrofaunal abundance

A total of 25,101 macrofaunal individuals were counted in 2011, with mean abundance ranging from 147 to 430 animals per grab (Table 5.1). The greatest number of animals occurred at station B12 where species richness was also highest. The fewest animals occurred at station B8, the site which also had the lowest species richness. No spatial patterns in abundance related to the outfall were observed. Except for station B8, values recorded during the year were within the historical range of 162–1074 individuals/grab reported between 1991–2010, and 91% of stations were within the tolerance interval bounds for macrofaunal abundance (230–671 individuals/grab) calculated for the region.

Species diversity, evenness, and dominance

Shannon diversity (H'), evenness (J'), and Swartz dominance (Dom) results for the PLOO stations sampled in 2011 are summarized in Table 5.1. H' values averaged from 3.1 to 4.4 at the different stations, while J' averaged from 0.72 to 0.93. These results are similar to historical values reported between 1991–2010 and suggest that local benthic assemblages remained characterized by relatively high numbers of evenly distributed species. There were also no patterns in diversity or evenness relative to the discharge site with both the highest and lowest values occurring south of the outfall at stations E9 and E1, respectively. Except for these two stations, average diversity values in 2011 were within regional tolerance intervals (H' = 3.4–4.3). In contrast, average evenness values were above the upper tolerance interval bound (J' = 0.86) at 16 of 22 stations and below the lower bound (J' = 0.75) at one station.

Swartz dominance values averaged from 20 to 52 species per station. The highest dominance (lowest index value) occurred at station E1 located inshore of the LA5 disposal site, while the lowest dominance (highest index value) occurred at station E9 located southwest of the PLOO. Dominance values in 2011 were generally similar to historical values, and except for stations E3 and E9 were within regional tolerance intervals (Dom = 7–44).

Benthic response index

Benthic response index (BRI) values are an important tool for gauging possible anthropogenic impacts to marine environments throughout the SCB. Values below 25 are considered indicative of reference conditions, values 25–33 represent “a minor deviation from reference conditions,” and values ≥34 represent increasing levels of degradation (Smith et al. 2001). All of the benthic samples collected off Point Loma in 2011 had BRI values <25 (Table 5.1). The highest average value (BRI = 22) occurred at station E14 located about 120 m from the end of the main outfall pipe (center of the wye), while the lowest values (BRI = 8) occurred at stations B8 and E1 located about 10 km north and 4 km south of the PLOO, respectively. Only BRI values for station E14 were above the upper tolerance interval of 15 for the PLOO region (City of San Diego 2007).

Table 5.2
Percent composition of species and abundance by major taxonomic group (phylum) for PLOO benthic stations sampled during 2011. Data are expressed as annual means (range) for all stations combined; $n = 22$.

Phyla	Species (%)	Abundance (%)
Annelida (Polychaeta)	48 (44–83)	60 (28–85)
Arthropoda (Crustacea)	22 (9–33)	20 (8–35)
Mollusca	17 (1–20)	6 (1–18)
Echinodermata	5 (1–13)	12 (1–58)
Other Phyla	8 (1–9)	2 (1–5)

Dominant Species

Polychaete worms were the dominant taxonomic group found in the PLOO region in 2011 and accounted for 48% of all species collected (Table 5.2). Crustaceans accounted for 22% of species reported, while molluscs, echinoderms, and all other taxa combined accounted for the remaining 17%, 5%, and 8%, respectively. Polychaetes were also the most numerous animals, accounting for 60% of the total abundance. Crustaceans accounted for 20% of the animals collected, molluscs 6%, echinoderms 12%, and the remaining phyla 2%. Overall, the percentage of taxa that occurred within each major taxonomic grouping and their relative abundances were similar to those observed in 2010 (City of San Diego 2011).

Table 5.3

The 10 most abundant macroinvertebrates collected at the PLOO benthic stations during 2011. Abundance values are expressed as mean number of individuals per 0.1-m^2 grab sample. Percent occurrence = percent of total samples where the species was collected.

Species	Taxonomic Classification	Abundance per Sample	Percent Occurrence
Amphiodia urtica	Echinodermata: Ophiuroidea	23.1	93
Chloeia pinnata	Polychaeta: Amphinomidae	9.5	70
Euphilomedes producta	Arthropoda: Ostracoda	8.8	86
Chaetozone hartmanae	Polychaeta: Cirratulidae	8.7	92
Prionospio (*Prionospio*) *jubata*	Polychaeta: Spionidae	8.3	93
Euphilomedes carcharodonta	Arthropoda: Ostracoda	8.2	77
Spiophanes berkeleyorum	Polychaeta: Spionidae	7.0	92
Aricidea (*Acmira*) *catherinae*	Polychaeta: Paraonidae	6.8	82
Lumbrineris cruzensis	Polychaeta: Lumbrineridae	6.6	72
Paraprionospio alata	Polychaeta: Spionidae	6.3	97

The 10 most abundant species included seven polychaetes, two crustaceans, and one echinoderm (Table 5.3). The dominant polychaetes were the amphinomid *Chloeia pinnata*, the cirratulid *Chaetozone hartmanae*, the spionids *Prionospio* (*Prionospio*) *jubata*, *Spiophanes berkeleyorum* and *Paraprionospio alata*, the paraonid *Aricidea* (*Acmira*) *catherinae,* and the lumbrinerid *Lumbrineris cruzensis*. Dominant crustaceans were the ostracods *Euphilomedes producta* and *E. carcharodonta*. The dominant echinoderm was the ophiuroid *Amphiodia urtica*, which was also the most abundant species collected during the year at an average of ~23 individuals per grab. Although this brittle star occurred at every site and accounted for ~11% of all benthic invertebrates collected, its abundances in 2011 were the lowest they have been since monitoring began (Figure 5.2). The most widely distributed species was *Paraprionospio alata*, which occurred in 97% of the samples.

BACIP Analyses

BACIP t-tests indicate that there has been a net change in the mean difference of species richness, BRI values, and *Amphiodia* spp abundance between impact site E14 and both control sites since the onset of wastewater discharge from the PLOO (Table 5.4). There also has been a net change in infaunal abundance between E14 and control site B9, and a net change in *Ampelisca* spp abundance between E14 and E26. The change in species richness is likely driven by increased variability and higher numbers of species at E14 beginning in 1997 (Figure 5.3A). The BACIP results for total infaunal abundances were more ambiguous (Figure 5.3B). While the difference in mean abundances between stations B9 and E14 has changed since discharge began, no significant change is apparent at the second control site (station E26). Changes in BRI differences generally have occurred due to increased index values at station E14 since 1994 (Figure 5.3C). The change in the difference in mean abundance of ampeliscid amphipods (i.e., *Ampelisca*) between E14 and E26 occurred more recently, beginning around 2003 (Figure 5.3D). The variable nature of *Ampelisca* populations at the three stations makes interpretation of this relatively small difference difficult. Significant differences in *Amphiodia* populations reflect both a decrease in the number of ophiuroids collected at E14 and a general increase at the control stations that occurred until about 2006 (Figure 5.3E). *Amphiodia* spp densities at station E14 in 2011 are in range of the low densities reported since about 1999. While populations of this brittle star have also declined in recent years at both control sites, their densities at these sites are more similar to pre-discharge values than to densities near the outfall. Finally, no significant changes in the difference in mean abundances

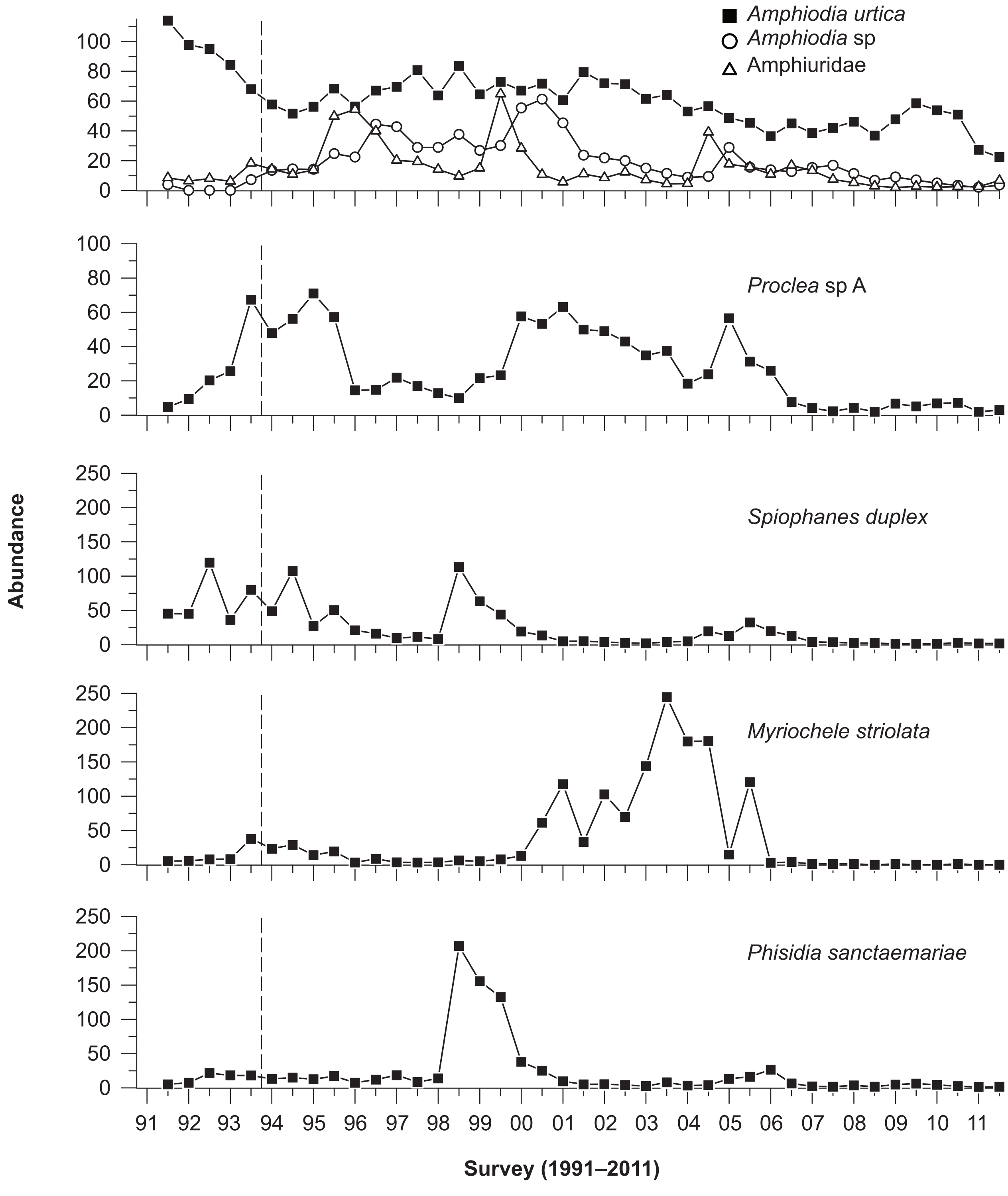

Figure 5.2

Abundance per survey for each of the five most abundant species (taxa) at the PLOO benthic stations sampled between 1995–2011. *Amphiodia urtica* and unidentifiable juveniles (*Amphiodia* sp and Amphiuridea) are graphed together; note expanded scale for *Spiophanes duplex*, *Myriochele striolata*, and *Phisidia sanctaemariae*. Data are expressed as mean values of biannual (i.e., first and third quarters) samples during each survey ($n=44$); samples were limited to primary core stations ($n=24$) during the quarters 03-3, 04-3, 05-1, 08-3, and 09-1 due to regulatory relief to accommodate special projects; prior to 2003, $n=42$. Dashed lines indicate onset of wastewater discharge.

Table 5.4

Results of BACIP t-tests for species richness (SR), infaunal abundance, BRI, and abundance of several representative taxa around the PLOO (1991–2011). Critical t-value = 1.680 for $\alpha = 0.05$ (one-tailed t-tests, df = 63); ns = not significant.

Variable	Control vs. Impact	t	*p*
SR	E26 vs E14	-3.15	0.001
	B9 vs E14	-3.44	0.001
Abundance	E26 vs E14	-1.44	ns
	B9 vs E14	-2.68	0.005
BRI	E26 vs E14	-13.25	< 0.001
	B9 vs E14	-9.82	< 0.001
Ampelisca spp	E26 vs E14	-1.79	0.039
	B9 vs E14	-1.18	ns
Amphiodia spp	E26 vs E14	-6.26	< 0.001
	B9 vs E14	-4.33	< 0.001
Rhepoxynius spp	E26 vs E14	-0.55	ns
	B9 vs E14	-0.37	ns

of phoxocephalid amphipods (i.e., *Rhepoxynius*) at the impact and control sites have occurred over time.

Classification of Macrobenthic Assemblages

The results of a 1-way ANOSIM examining the relationship of invertebrate communities by sediment type revealed significant differences between assemblages occurring in sandy sediments with a high fraction of fines and assemblages occurring in fine sediments with a high fraction of sand (pairwise r = 0.854, Appendix D.1) (see Chapter 4 for sediment type details). Differences in these assemblages were characterized by minor variations in abundances of many common taxa. The five species with the greatest contribution to differences (~2% each) were the polychaetes *Chaetozone hartmanae* and *Chloeia pinnata*, and the ostracod *Euphilomedes carcharodonta* (all three of which were absent in fine sediments with a sand fraction), the ostracod *Euphilomedes producta* (which was more abundant in sandier sediments), and the ophiuroid *Amphiodia urtica* (which was more abundant in finer sediments). No other pairwise tests comparing benthic communities between sediment types were significant.

Discrimination of cluster groups

Classification (cluster) analysis was used to discriminate between invertebrate communities from individual grab samples, resulting in four ecologically-relevant SIMPROF-supported groups (Figure 5.4, Table 5.5). These "assemblages," referred to herein as cluster groups A through D contained between 1–66 grabs each, and exhibited mean species richness values ranging from 64 to 106 taxa per grab and mean abundances of 200 to 315 individuals per grab (Table 5.5). Grabs within each cluster generally were collected from sites with similar depth and sediment characteristics (Appendix D.2). For example, cluster groups A and B were restricted to samples from three 88-m stations that had percent fines of 46–60%, while cluster group C represented samples from one 98-m station and three 116-m stations where percent fines ranged between 28–40%.

Description of cluster groups

Cluster group A consisted of a single July grab collected at station B11, the northernmost 88-m site sampled in the region (Figure 5.4). Species richness and abundance were 94 taxa and 234 individuals/grab, respectively (Table 5.5). Sediments consisted of 53.6% sand and 46.4% fines (Appendix D.2). The five most abundant species encountered were the polychaetes *Chloeia pinnata*, *Prionospio* (*Prionospio*) *jubata, Chaetozone hartmanae,* and *Paraprionospio alata,* and the amphipod *Ampelisca pugetica.* Abundance of these species ranged from 7 to 38 individuals/grab.

Cluster group B consisted of all four grabs from station B8, and three grabs from station E1 (Figure 5.4). This group had the lowest average species richness and abundance of any cluster group at 64 taxa and 200 individuals/grab, respectively (Table 5.5). Sediments averaged 52.2% fines with significant fractions of sand (Appendix D.2). Ophiuroids (brittle stars) dominated this group, with approximately 69 *Amphiodia urtica* occurring in each grab. The polychaetes *Lumbrineris cruzensis*,

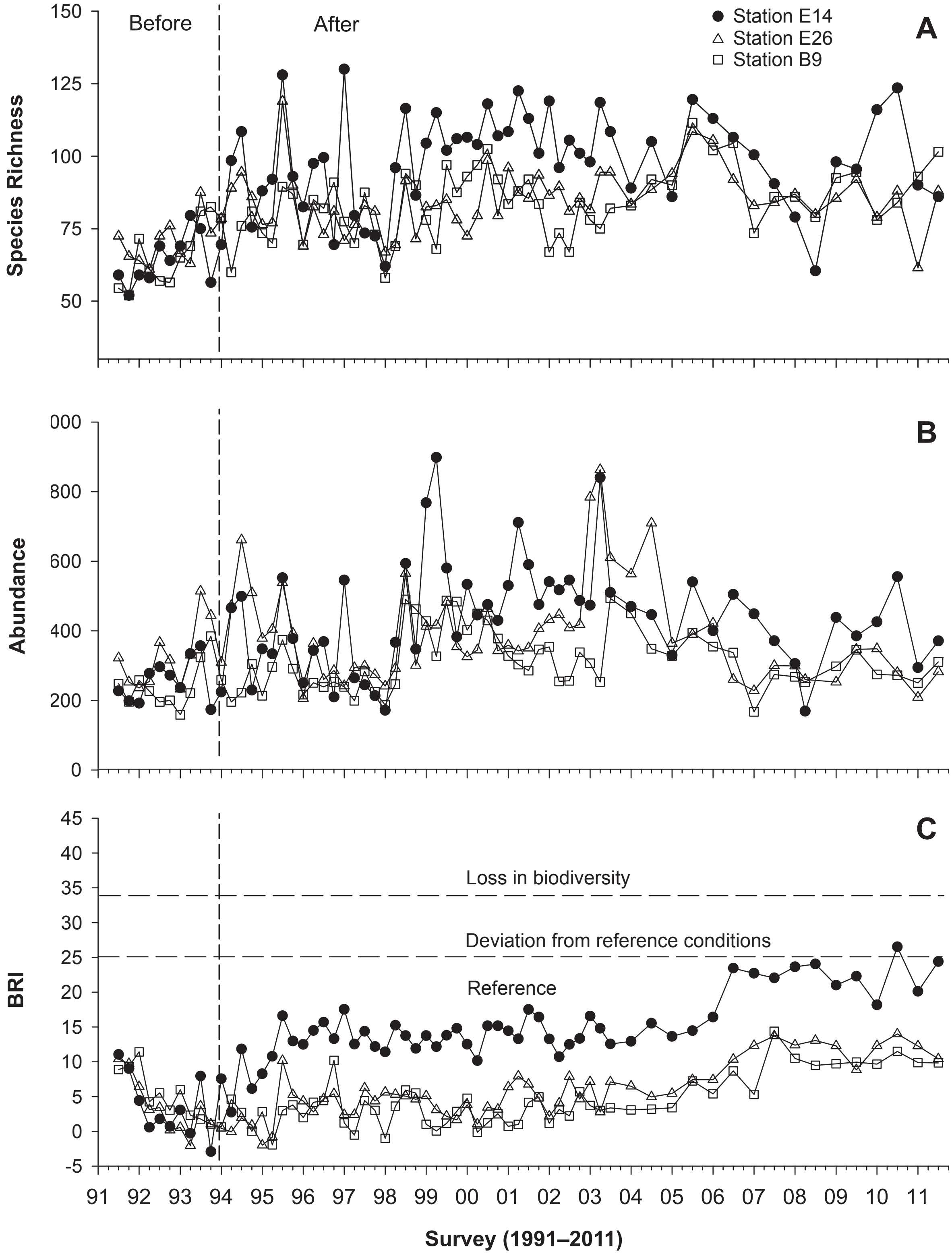

Figure 5.3

Comparison of several parameters at "impact" site (station E14) and "control" sites (stations E26, B9) used in BACIP analyses (see Table 5.4) between 1991–2011. Parameters include: (A) species richness; (B) infaunal abundance; (C) benthic response index (BRI); (D) abundance of *Ampelisca* spp; (E) abundance of *Amphiodia* spp. Data for each station are expressed as means per 0.1 m^2 ($n = 2$ per survey).

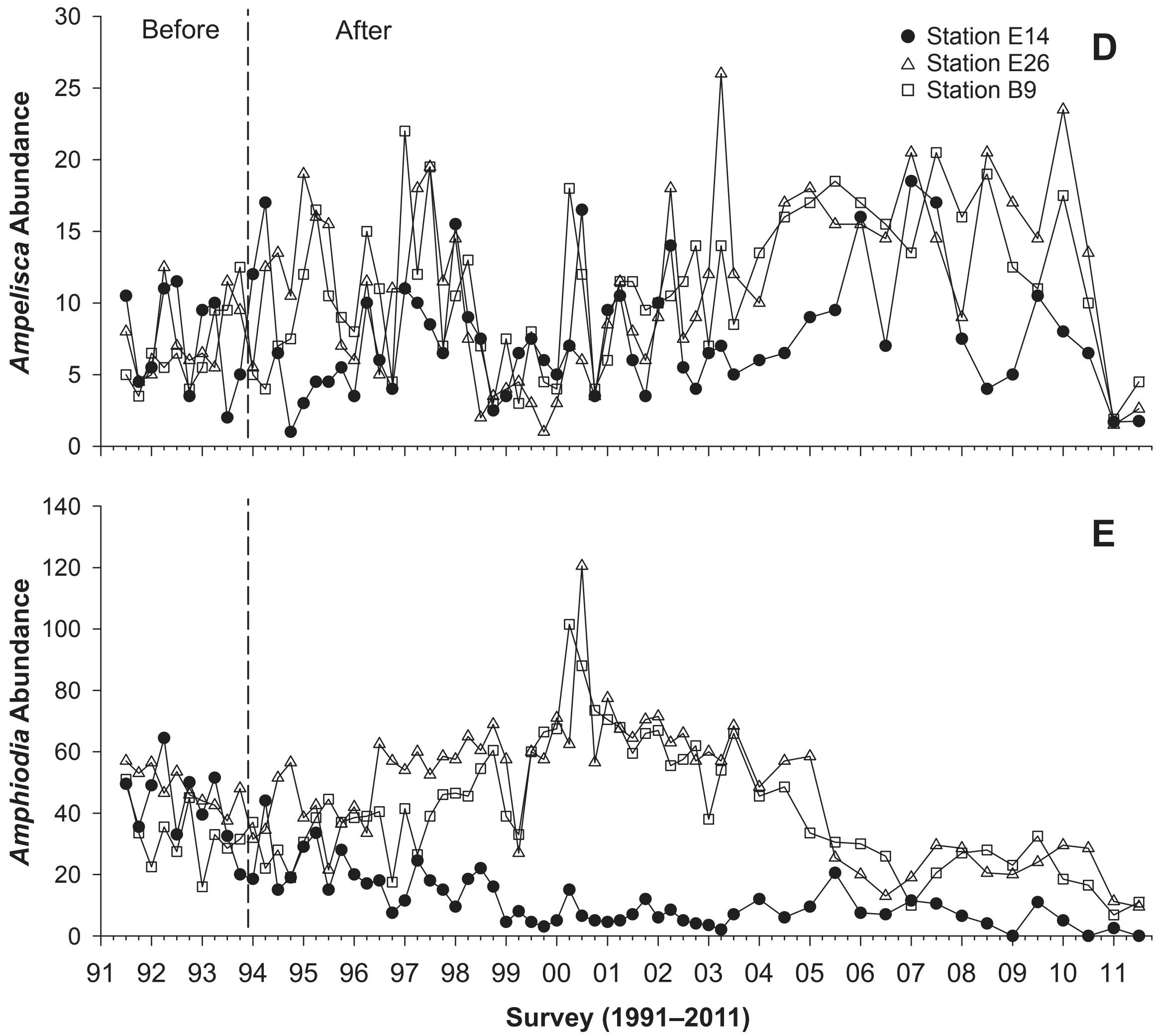

Figure 5.3 *continued*

Travisia brevis and *Sternaspis fossor*, and the bivalve *Ennucula tenuis* were also very common, averaging between 6–7 individuals per grab. No other species had abundances >4/grab. SIMPER revealed *A. urtica*, *E. tenuis*, *S. fossor*, and the polychaete *Paraprionospio alata* and amphipod *Rhepoxynius bicuspidatus* to be the five most characteristic species of the assemblage.

Cluster group C consisted of 14 grabs from four sites located at 98-m and 116-m depths, including all grabs from stations B10, B12 and E3, and the two January grabs from station E9 (Figure 5.4). Average species richness and abundance were the highest of all cluster groups with 106 taxa and 315 individuals/grab, respectively (Table 5.5). The sediments in this group had the lowest percent fines, averaging only 34% (Appendix D.2). The five most abundant species encountered were the polychaetes *Chloeia pinnata, Prionospio* (*Prionospio*) *jubata, Spiophanes kimballi, Aphelochaeta glandaria* Cmplx and *Chaetozone hartmanae*, all of which averaged between 7–14 individuals/grab. SIMPER revealed *A. glandaria* Cmplx*, C. pinnata, S. kimballi,* the amphipod *Ampelisca careyi,* and the ophiuroid *Amphiodia digitata* be the five most characteristic species of the assemblage.

Cluster group D consisted of 75% of all grabs sampled during the year (Figure 5.4). The cluster group possessed grabs from all nearfield sites, as well as the majority of sites located both north and south of the outfall (Figure 5.4). Average species richness and abundance were 87 taxa and 289 individuals/grab, respectively (Table 5.5). The five most abundant species were the ophiuroid

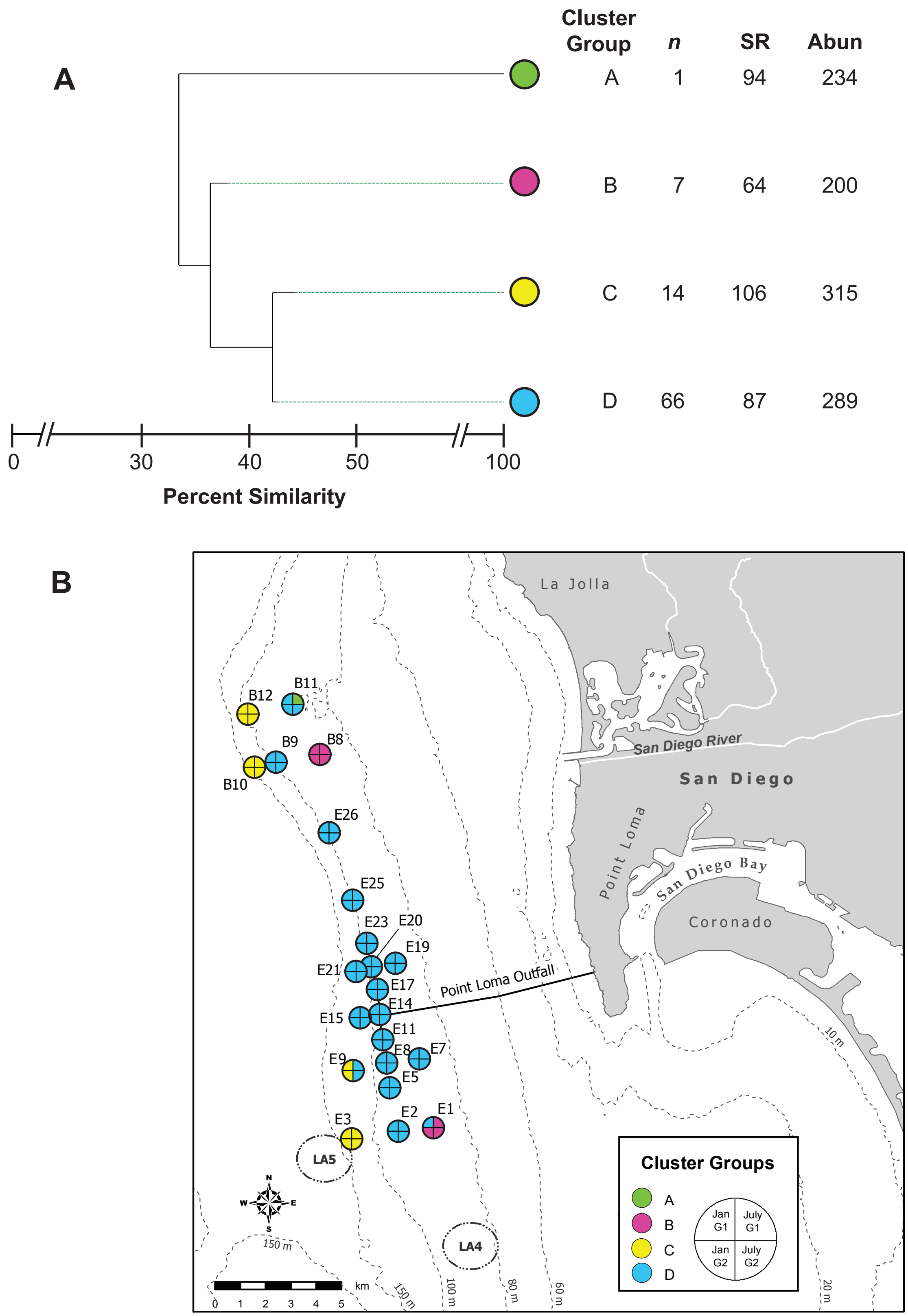

Figure 5.4
(A) Cluster analysis of macrofaunal assemblages at PLOO stations sampled during 2011. Data for species richness (SR) and infaunal abundance (Abun) are expressed as mean values per 0.1-m^2 over all stations in each group (*n*). (B) Spatial distribution of cluster groups in the PLOO region. Colors of each circle correspond to colors in the dendrogram.

Table 5.5

Mean abundance of the most common species found in cluster groups A–D (defined in Figure 5.4). Bold values indicate taxa that were considered among the most characteristic of that group according to SIMPER analysis.

	Cluster Groups			
Taxa	**A**[a]	**B**	**C**	**D**
Chloeia pinnata	38.0	0.3	**13.6**	9.1
Prionospio (*Prionospio*) *jubata*	13.0	1.7	9.0	**8.8**
Chaetozone hartmanae	12.0	0.1	7.4	**9.8**
Paraprionospio alata	8.0	**3.9**	6.3	6.6
Ampelisca pugetica	7.0	0.4	1.7	1.3
Amphiodia urtica	3.0	**68.7**	2.4	**23.0**
Lumbrineris cruzensis	3.0	6.6	1.2	7.9
Travisia brevis	3.0	6.0	1.9	2.2
Ennucula tenuis	2.0	**5.7**	1.6	3.0
Sternaspis fossor	1.0	**5.6**	4.0	5.4
Spiophanes kimballi	3.0	1.0	**8.8**	5.4
Aphelochaeta glandaria Cmplx	1.0	0.3	**8.1**	4.8
Euphilomedes producta	0.0	0.7	5.4	**10.6**
Euphilomedes carcharodonta	0.0	0.1	2.6	**10.3**

[a] SIMPER analyses only conducted on cluster groups that contain more than one benthic grab.

Amphiodia urtica, the ostracods *Euphilomedes carcharodonta* and *Euphilomedes producta*, and the polychaetes *Chaetozone hartmanae* and *Chloeia pinnata*, all of which occurred at densities of 9–23 individuals/grab. SIMPER revealed *A. urtica*, *C. hartmanae*, *E. carcharodonta*, *E. producta*, and the polychaete *Prionospio* (*Prionospio*) *jubata* to be the five most characteristic taxa of the assemblage.

Discussion

Benthic communities across the Point Loma outfall region in 2011 were similar to those encountered during previous years, including the period before wastewater discharge (see City of San Diego 1995, 2011). These communities remained dominated by ophiuroid-polychaete based assemblages. Although the brittle star *Amphiodia urtica* remained the most abundant species off Point Loma, its overall population abundances were the lowest since monitoring began about 20 years ago. The spionid polychaete *Paraprionospio alata* was the most widespread benthic invertebrate encountered during the year, which represents a resurgence of its prominence in the region. The overall abundance and dominance of most species typically were within historical ranges (e.g., City of San Diego 1995, 1999, 2007, 2011). One exception is that populations of the spionid polychaete *Spiophanes duplex* have shown a notable decrease over the past few years. As previously reported, most sites along the 98-m isobath spanning the PLOO discharge site had sandy sediments with a high fraction of fines that supported similar types of benthic communities. Most variability in macrofaunal populations occurred at sites located several kilometers to the north and south of the outfall that possessed slightly higher fractions of coarse or fine sediments. Put into a broader regional context, values for diversity, evenness and dominance off Point Loma were within ranges of those described for other areas of the SCB (Thompson et al. 1993b, Bergen et al. 1998, 2000, 2001, Ranasinghe et al. 2003, 2007), and sites surveyed off Point Loma during the year were found to have species assemblages similar to those described for other areas in southern California (e.g., Barnard and Ziesenhenne 1961, Jones 1969, Fauchald and Jones 1979, Thompson et al. 1987, 1993b, Zmarzly et al. 1994, Diener and Fuller 1995, Bergen et al. 1998, 2000, 2001, Ranasinghe et al. 2010).

Changes in populations of pollution-sensitive or pollution-tolerant species or other indicators of benthic condition have shown no evidence of significant environmental degradation off Point Loma. For instance, the brittle star *Amphiodia urtica* is a well-known dominant of mid-shelf, mostly fine sediment habitats in the SCB that is sensitive to changes near wastewater outfalls. Although populations of *A. urtica* have decreased significantly near the discharge site (i.e., station E14) over the past 15 or more years, there has been a region-wide decrease in this species as well, especially during the past year (see above). Although long-term changes in *A. urtica* populations at station E14 may be related to organic enrichment, factors such as altered sediment composition (e.g., coarser sediments) and increased predation pressure near the outfall may also be important. Regardless of the cause of these changes, abundances of *A. urtica* off Point Loma remain within the range of natural variation in SCB populations. Another important indicator species in the SCB is the opportunistic polychaete *Capitella teleta* (previously considered within the *Capitella capitata* species complex), which can reach densities as high as 5000/m^2 in polluted sediments (e.g., Reish 1957, Swartz et al. 1986). Although populations of *C. teleta* have fluctuated off Point Loma, overall abundances of this species have remained low and characteristic of undisturbed habitats. For example, the highest number *C. teleta* observed over the past decade occurred in 2009 when a total of 206 individuals were recorded, 97% of which occurred at nearfield stations E11, E14 and E17 (City of San Diego 2010). Abundances of *C. teleta* were very low in 2011 with only a total of seven individuals reported. Further, populations of pollution-sensitive phoxocephalid amphipods in the genus *Rhepoxynius* have remained stable at the nearfield sites, suggesting that wastewater discharge has had little to no effect on these species. Finally, although benthic response index (BRI) values have increased at station E14 as well as at two other nearfield stations (E11 and E17) since outfall operations began, overall BRI values in 2011 were indicative of undisturbed areas (Smith et al. 2001, Ranasinghe et al. 2010).

In conclusion, benthic macrofaunal communities appear to be in good condition off Point Loma, with all of the sites surveyed in 2011 being classified in reference condition based on assessments using the BRI. This agrees with findings in Ranasinghe et al. (2010, 2012) who reported that at least 98% of the entire SCB mainland shelf is in good condition based on data from bight-wide surveys. Most communities near the PLOO remain similar to natural indigenous assemblages characteristic of the San Diego region (see Chapter 9 in City of San Diego 2012), although some minor changes in component species or community structure have appeared near the outfall. However, it is not currently possible to definitively determine whether these observed changes are due to habitat alteration related to organic enrichment, physical structure of the outfall, or a combination of factors. In addition, abundances of soft bottom marine invertebrates exhibit substantial natural spatial and temporal variability that may mask the effects of disturbance events (Morrisey et al. 1992a, 1992b, Otway 1995), and the effects associated with the discharge of advanced primary treated sewage may be difficult to detect in areas subjected to strong currents that facilitate rapid dispersion of the wastewater plume (Diener and Fuller 1995).

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